Haweswater Aqueduct Resilience Programme - Proposed Bowland Section

Environmental Statement

Volume 4

Appendix 10.4: Geophysical Survey of Proposed Lower Houses Compound

June 2021

Water for the North West

Haweswater Aqueduct Resilience Programme - Proposed Bowland Section

Project No:	B27070CT
Document Title:	Proposed Bowland Section Environmental Statement Volume 4 Appendix 10.4: Geophysical Survey of Proposed Lower Houses Compound
Document Ref.:	LCC_RVBC-BO-TA-010-004
Revision:	0
Date:	June 2021
Client Name:	United Utilities Water Ltd

Jacobs U.K. Limited

5 First Street
Manchester M15 4GU
United Kingdom
T +44 (0)161 235 6000
F +44 (0)161 235 6001
www.jacobs.com

Geophysical Survey Report

Proposed Lower Houses Compound Haweswater Aqueduct Resilience Programme – Proposed Bowland Section

For

ADAS

On Behalf Of

United Utilities

Magnitude Surveys Ref: MSSD897

April 2021

Unit 17, Commerce Court

Challenge Way

Bradford

BD4 8NW

01274 926020

info@magnitudesurveys.co.uk

Report By:

Robert Kenyon BSc (Hons) MSc

Alison Langston BA PCIfA

Report Approved By:

Dr Kayt Armstrong MCIfA

Issue Date:

20 April 2021

Abstract

Magnitude Surveys was commissioned to assess the subsurface archaeological potential of a c. 10.78ha area of land at the Proposed Lower Houses Compound, Lancashire. No anomalies suggestive of significant archaeological activity have been identified. Anomalies of an agricultural origin have been identified across the survey area, including a mapped former field boundary, ploughing regimes including possible evidence of post-medieval ploughing in the northeast, and drainage features. Anomalies of an undetermined origin have also been detected in the northeast of the survey area, and while an archaeological origin cannot be ruled out, an agricultural origin is considered more likely, given the surrounding anomalies. Sources of modern interference have been predominantly identified around field edges, and associated roads, and have not had a large impact on the reliability of the survey.

Contents

List of Figures

1. Introduction

1.1. Magnitude Surveys Ltd (MS) was commissioned by ADAS on behalf of United Utilities to undertake a geophysical survey over a c. 10.78ha area of land at the Proposed Lower Houses Compound, Lancashire (SD 63593 65556).

1.2. The geophysical survey comprised hand-pulled cart-mounted, and hand-carried GNSS-positioned fluxgate gradiometer survey. Magnetic survey is the standard primary geophysical method for archaeological applications in the UK due to its ability to detect a range of different features. The technique is particularly suited for detecting fired or magnetically enhanced features, such as ditches, pits, kilns, sunken featured buildings and industrial activity (David *et al.*, 2008).

1.3. The survey was conducted in line with the current best practice guidelines produced by the Chartered Institute for Archaeologists (CIfA, 2020) and the European Archaeological Council (Schmidt *et al.,* 2015).

1.4. It was conducted in line with a WSI produced by MS (Adams, 2021).

1.5. The survey commenced on 12/04/2021 and took 2 days to complete.

2. Quality Assurance

2.1. Magnitude Surveys is a Registered Organisation of the Chartered Institute for Archaeologists (CIfA), the chartered UK body for archaeologists, and a corporate member of ISAP (International Society for Archaeological Prospection).

2.2. The directors of MS are involved in cutting edge research and the development of guidance/policy. Specifically, Dr Chrys Harris has a PhD in archaeological geophysics from the University of Bradford, is a Member of CIfA and is the Vice-Chair of the International Society for Archaeological Prospection (ISAP); Finnegan Pope-Carter has an MSc in archaeological geophysics and is a Fellow of the London Geological Society, as well as a member of GeoSIG (CIfA Geophysics Special Interest Group); Dr Kayt Armstrong has a PhD in archaeological geophysics from Bournemouth University, is a Member of CIfA, the Editor of ISAP News, and is the UK Management Committee representative for the COST Action SAGA; Dr Paul Johnson has a PhD in archaeology from the University of Southampton, is a Fellow of the Society of Antiquaries of London, has been a member of the ISAP Management Committee since 2015, and is currently the nominated representative for the EAA Archaeological Prospection Community to the board of the European Archaeological Association.

2.3. All MS managers, field and office staff have degree qualifications relevant to archaeology or geophysics and/or field experience.

3. Objectives

3.1. The objective of this geophysical survey was to assess the subsurface archaeological potential of the survey area.

4. Geographic Background

4.1. The survey area was located c. 2.1 km northwest of Lowgill, Lancashire (Figure 1). Gradiometer survey was undertaken across seven pasture fields. The survey area was bounded on all sides by agricultural land, the only exception being the southwestern extent which was bounded by a minor road (Figure 2).

4.2. Survey considerations:

Survey Area	Ground Conditions	Further Notes
1	The survey area consisted of a mostly flat pasture field, with a small section in the south steeply sloping down to the north.	The survey area was bounded on all sides by wood and wire fencing with a gate in the northeast corner. A ditch and a footpath were present on the northern boundary, and a metal feeder was present in the centre of the area, along with a borehole in the east. A small area in the south area was steeply sloped and overgrown with vegetation, preventing survey.
2	The survey area consisted of a pasture field, gently sloping down to the south.	The survey area was bounded by wood and wire fencing in the northeast, southeast and southwest, with no physical boundary to the northwest. A metal gate was present on the north-eastern boundary with a metal feeder to the north.
3	The survey area consisted of a pasture field, gently sloping down to the southeast.	The survey area was bounded to the northeast, east and northwest by wire fencing, with a ditch along part of the northeast boundary, and with no physical boundary to the south.
4	The survey area consisted of a pasture field, gently sloping down to the west.	The survey area was bounded to the west by wood and wire fencing, with no physical boundary to the north, east and south.
5	The survey area consisted of a pasture field, gently sloping down to the east.	The survey area was bounded to the north, northwest and east by wood and wire fencing, with no physical boundary to the southeast and southwest.
6	The survey area consisted of a pasture field, gently sloping down to the east.	The survey area was bounded to the northwest and southeast by wood and wire fencing, with no physical boundary to the northeast and southwest.
7	The survey area consisted of a pasture field, gently sloping down to the south.	The survey area had no physical boundary on all sides.

4.3. The underlying geology across the survey area comprises siltstone and sandstone of the Claughton Member. Superficial deposits comprise Devensian Till across much of the survey area, with the exception of a small band across Areas 1 & 6 where no superficial deposits were recorded (British Geological Survey, 2021).

4.4. The soils consist of slowly permeable, seasonally wet acidic loamy and clayey soils in Areas 1, 3, 4, 5, 6 and 7 and the northeast of Area 2. The southwest of Area 2 comprises of slowly permeable wet, very acidic upland spoils with a peaty surface (Soilscapes, 2021).

5. Archaeological Background

5.1. The following is a summary of Historic Environment Record data provided by ADAS and an environmental statement produced by Jacobs (2019) and provided by ADAS. Above ground assets such as farm buildings have not been included.

5.2. No known archaeological remains are recorded within the survey area. Within the vicinity of the survey area three assets are recorded, including a lynchet earthwork (PRN27274) on the eastern boundary of the survey area, Ridge and Furrow regimes (PRN27287 & PRN27271) c. 38m to the east and a quarry (PRN27273) c. 82m to the east.

5.3. The survey area is located within a landscape characterised as Ancient Enclosures. This type of landscape consists of an irregular enclosure pattern with curvilinear field boundaries which date from before the 17th century.

5.4. A map regression shows limited changes to the landscape since Ordnance Survey Mapping from 1885-1900. There appear to be no changes to boundaries within the survey area bar the removal of one field division visible in 2nd Edition OS Mapping.

6. Methodology

6.1. Data Collection

6.1.1. Magnetometer surveys are generally the most cost effective and suitable geophysical technique for the detection of archaeology in England. Therefore, a magnetometer survey should be the preferred geophysical technique unless its use is precluded by any specific survey objectives or the site environment. For this site, no factors precluded the recommendation of a standard magnetometer survey. Geophysical survey therefore comprised the magnetic method as described in the following section.

6.1.2. Geophysical prospection comprised the magnetic method as described in the following table.

6.1.3. Table of survey strategies:

Method	Instrument	Traverse Interval	Sample Interval
Magnetic	Bartington Instruments Grad-13 Digital Three-Axis Gradiometer	1m	200Hz reprojected to 0.125m

6.1.4. The magnetic data were collected using MS' bespoke hand-pulled cart system and hand-carried GNSS-positioned system.

6.1.4.1. MS' cart and hand-carried systems were comprised of Bartington Instruments Grad 13 Digital Three-Axis Gradiometers. Positional referencing was through a multi-channel, multi-constellation GNSS Smart Antenna RTK GPS outputting in NMEA mode to ensure high positional accuracy of collected measurements. The

RTK GPS is accurate to 0.008m + 1ppm in the horizontal and 0.015m + 1ppm in the vertical.

6.1.4.2. Magnetic and GPS data were stored on an SD card within MS' bespoke datalogger. The datalogger was continuously synced, via an in-field Wi-Fi unit, to servers within MS' offices. This allowed for data collection, processing and visualisation to be monitored in real-time as fieldwork was ongoing.

6.1.4.3. A navigation system was integrated with the RTK GPS, which was used to guide the surveyor. Data were collected by traversing the survey area along the longest possible lines, ensuring efficient collection and processing.

6.2. Data Processing

6.2.1. Magnetic data were processed in bespoke in-house software produced by MS. Processing steps conform to the EAC and Historic England guidelines for 'minimally enhanced data' (see Section 3.8 in Schmidt *et al.*, 2015: 33 and Section IV.2 in David *et al.,* 2008: 11).

Sensor Calibration – The sensors were calibrated using a bespoke in-house algorithm, which conforms to Olsen *et al*. (2003).

Zero Median Traverse – The median of each sensor traverse is calculated within a specified range and subtracted from the collected data. This removes striping effects caused by small variations in sensor electronics.

Projection to a Regular Grid – Data collected using RTK GPS positioning requires a uniform grid projection to visualise data. Data are rotated to best fit an orthogonal grid projection and are resampled onto the grid using an inverse distance-weighting algorithm.

Interpolation to Square Pixels – Data are interpolated using a bicubic algorithm to increase the pixel density between sensor traverses. This produces images with square pixels for ease of visualisation.

6.3. Data Visualisation and Interpretation

6.3.1. This report presents the gradient of the sensors' total field data as greyscale images, as well as the total field data from the lower sensors. The gradient of the sensors minimises external interferences and reduces the blown-out responses from ferrous and other high contrast material. However, the contrast of weak or ephemeral anomalies can be reduced through the process of calculating the gradient. Consequently, some features can be clearer in the respective gradient or total field datasets. Multiple greyscale images of the gradient and total field at different plotting ranges have been used for data interpretation. Greyscale images should be viewed alongside the XY trace plot (Figures 8 & 11). XY trace plots visualise the magnitude and form of the geophysical response, aiding anomaly interpretation.

6.3.2. Geophysical results have been interpreted using greyscale images and XY traces in a layered environment, overlaid against open street maps, satellite imagery, historical maps, LiDAR data, and soil and geology maps. Google Earth (2021) was also consulted, to compare the results with recent land use.

6.3.3. Geodetic position of results – All vector and raster data have been projected into OSGB36 (ESPG27700) and can be provided upon request in ESRI Shapefile (.SHP) and Geotiff (.TIF) respectively. Figures are provided with raster and vector data projected against OS Open Data.

7. Results

7.1. Qualification

7.1.1. Geophysical results are not a map of the ground and are instead a direct measurement of subsurface properties. Detecting and mapping features requires that said features have properties that can be measured by the chosen technique(s) and that these properties have sufficient contrast with the background to be identifiable. The interpretation of any identified anomalies is inherently subjective. While the scrutiny of the results is undertaken by qualified, experienced individuals and rigorously checked for quality and consistency, it is often not possible to classify all anomaly sources. Where possible, an anomaly source will be identified along with the certainty of the interpretation. The only way to improve the interpretation of results is through a process of comparing excavated results with the geophysical reports. MS actively seek feedback on their reports, as well as reports from further work, in order to constantly improve our knowledge and service.

7.2. Discussion

7.2.1. An interpretation of the geophysical results are presented in combination with satellite imagery and historical maps (Figure 5).

7.2.2. A fluxgate gradiometer survey was carried out over c. 10.78ha of land at the Proposed Lower Houses Compound, Lancashire. The survey has responded well to the environment, although there are areas especially in the north and northwest, where magnetic interference is present and will have obscured any anomalies of agricultural or archaeological origin, if present. Otherwise, modern interference has been limited largely to the edges of the survey area.

7.2.3. No anomalies suggestive of an archaeological origin have been identified. However, anomalies indicative of past agricultural activity have been detected across the site and include a mapped former field boundary, along with indications of recent and historical ploughing regimes. In addition, drainage activity possibly relating to the streams and watercourses in the surrounding areas have been identified. One anomaly has been categorised as having an undetermined origin; this anomaly is considered likely to be agricultural or modern in origin. However, an archaeological origin should not be completely discounted.

7.3. Interpretation

7.3.1. General Statements

7.3.1.1. Geophysical anomalies will be discussed broadly as classification types across the survey area. Only anomalies that are distinctive or unusual will be discussed individually.

7.3.1.2. **Data Artefact** – Data artefacts usually occur in conjunction with anomalies with strong magnetic signals due to the way in which the sensors respond to very strong point sources. They are usually visible as minor 'streaking' following the line of data collection. While these artefacts can be reduced in post-processing through data filtering, this would risk removing 'real' anomalies. These artefacts are therefore indicated as necessary in order to preserve the data as 'minimally processed'.

7.3.1.3. **Ferrous (Spike)** – Discrete dipolar anomalies are likely to be the result of isolated pieces of modern ferrous debris on or near the ground surface.

7.3.1.4. **Magnetic Disturbance** – The strong anomalies produced by extant metallic structures, typically including fencing, pylons, vehicles and service pipes, have been classified as 'Magnetic Disturbance'. These magnetic 'haloes' will obscure weaker anomalies relating to nearby features, should they be present, often over a greater footprint than the structure causing them.

7.3.1.5. **Undetermined** – Anomalies are classified as Undetermined when the origin of the geophysical anomaly is ambiguous and there is no supporting contextual evidence to justify a more certain classification. These anomalies are likely to be the result of geological, pedological or agricultural processes, although an archaeological origin cannot be entirely ruled out. Undetermined anomalies are generally distinct from those caused by ferrous sources.

7.3.2. Magnetic Results - Specific Anomalies

7.3.2.1. **Agricultural (Weak/Trend) –** In the east of Area 5, a series of strong, positive parallel anomalies have also been identified [**5a**] (Figure 7) which are closely spaced, between c. 2-4m apart. It is probable that these are examples of later ridge and furrow cultivation, as they are more closely spaced than expected for earlier examples. These anomalies could be related to, or be continuations of, ridge and furrow cultivation (PRN27287 & PRN27271) which has been identified close to the survey area in the east (Section 5.2). However, the exact cause of these anomalies is not certain and it is possible that they are related to drainage or other post-Medieval agricultural activity. In addition, a weak, positive curvilinear anomaly has been identified in Area 1 which collocates with a former field boundary, present on 2nd Edition OS maps (Figure 5).

7.3.2.2. **Agricultural (Trend) –** Across much of the survey area, numerous linear trends have been identified (Figure 4). These parallel anomalies broadly align with ploughing trends observed though satellite imagery and will have been caused by this activity (Figure 5).

7.3.2.3. **Drainage Features –** Several linear anomalies, characterised by their alignments of dipolar anomalies, have been identified across the survey area (Figures 7 and 10). These anomalies are indicative of land drains, their magnetic signal being typical of fired clay drains.

7.3.2.4. **Undetermined (Strong) –** In the east of Area 5, a linear arrangement of discrete positive anomalies transects the survey area, orientated broadly north to south [**5b**] (Figure 7). Whilst this anomaly is close to a mapped footpath visible on the 2nd Edition OS maps (Figure 5), it does not appear to align with the general shape, and therefore is unlikely to be related. Moreover, the anomaly appears to have a close association with a very strong area of magnetic disturbance in the east and cuts across anomaly [**5a**] (Figure 7), suggestive of recent agricultural or other land use, rather than archaeology. It is possible that this anomaly could represent a land drain although an exact cause cannot be ascribed. As such an archaeological origin cannot be completely discounted.

8. Conclusions

8.1. A fluxgate gradiometer survey has been successfully undertaken across the survey area, with small areas unable to be surveyed due to the presence of overgrown vegetation. The survey has responded well across the survey area, with anthropogenic activity detected throughout, although some areas have been affected by magnetic interference, especially in the north. This may have obscured any weaker anomalies in its vicinity, if they were present. Other areas of modern disturbance are largely limited to the edges of survey areas, surrounding field boundaries and adjacent roads.

8.2. Evidence of historical and recent agricultural activity is visible in the form of linear trends. These include anomalies suggestive of possible post-medieval ploughing or ridge and furrow cultivation, in addition to drainage features. The survey also identified anomalies corresponding with a former field boundary.

8.3. No anomalies suggestive of significant archaeological activity have been identified. However, one anomaly has been categorised as ‘Undetermined’. While an agricultural or modern cause is considered likely for this anomaly, an archaeological origin cannot be completely discounted.

9. Archiving

9.1. MS maintains an in-house digital archive, which is based on Schmidt and Ernenwein (2013). This stores the collected measurements, minimally processed data, georeferenced and un-georeferenced images, XY traces and a copy of the final report.

9.2. MS contributes reports to the ADS Grey Literature Library upon permission from the client, subject to any dictated time embargoes.

10. Copyright

10.1. Copyright and intellectual property (IP) pertaining to all reports, figures and datasets produced by Magnitude Services Ltd is retained by MS. The client is given full licence to use such material for their own purposes. Permission must be sought by any third party wishing to use or reproduce any IP owned by MS.

11. References

Adams, C., 2021. Written Scheme of Investigation for a geophysical survey of the Proposed Lower Houses Compound, Lancashire. Magnitude Surveys. MSSD987.

British Geological Survey, 2021. Geology of Britain. Lowgill, Lancashire. [http://mapapps.bgs.ac.uk/geologyofbritain/home.html/]. Accessed 16/04/2021.

Chartered Institute for Archaeologists, 2020. Standards and guidance for archaeological geophysical survey. CIfA.

David, A., Linford, N., Linford, P. and Martin, L., 2008. Geophysical survey in archaeological field evaluation: research and professional services guidelines (2nd edition). Historic England.

Google Earth, 2021. Google Earth Pro V 7.1.7.2606.

Jacobs, 2019. Haweswater Aqueduct Resilience Programme - Proposed Bowland Section, Chapter 10 - Appendix 1, Environmental Statement

National Library of Scotland, 2021. Ordnance Survey Maps. [http://maps.nls.uk]. Accessed 16/04/2021.

Olsen, N., Toffner-Clausen, L., Sabaka, T.J., Brauer, P., Merayo, J.M.G., Jorgensen, J.L., Leger, J.M., Nielsen, O.V., Primdahl, F., and Risbo, T., 2003. Calibration of the Orsted vector magnetometer. Earth Planets Space 55: 11-18.

Schmidt, A. and Ernenwein, E., 2013. Guide to good practice: geophysical data in archaeology (2nd edition). Oxbow Books: Oxford.

Schmidt, A., Linford, P., Linford, N., David, A., Gaffney, C., Sarris, A. and Fassbinder, J., 2015. Guidelines for the use of geophysics in archaeology: questions to ask and points to consider. EAC Guidelines 2. European Archaeological Council: Belgium.

Soilscapes, 2021. Lowgill, Lancashire. Cranfield University, National Soil Resources Institute. [http://landis.org.uk]. Accessed16/04/2021.

12. Project Metadata

MS Job Code	MSSD897
Project Name	Proposed Lower Houses Compound Haweswater Aqueduct Resilience Programme – Proposed Bowland Section
Client	ADAS
Grid Reference	SD 63593 65556
Survey Techniques	Magnetometry
Survey Size (ha)	10.78 ha (Magnetometry)
Survey Dates	2021-04-12 to 2021-04-13
Project Lead	Christian Adams BA, MSc
Project Officer	Christian Adams BA, MSc
HER Event No	N/A
OASIS No	N/A
S42 Licence No	N/A
Report Version	1.0

13. Document History

Version	Comments	Author	Checked By	Date
0.1	Initial draft for Project Lead to Review	RK, AL	CA	19 April 2021
0.2	Corrections from Project Lead	AL	CA, KA	19 April 2021
1.0	Corrections from client and issued as final	CA	HB	18 May 2021

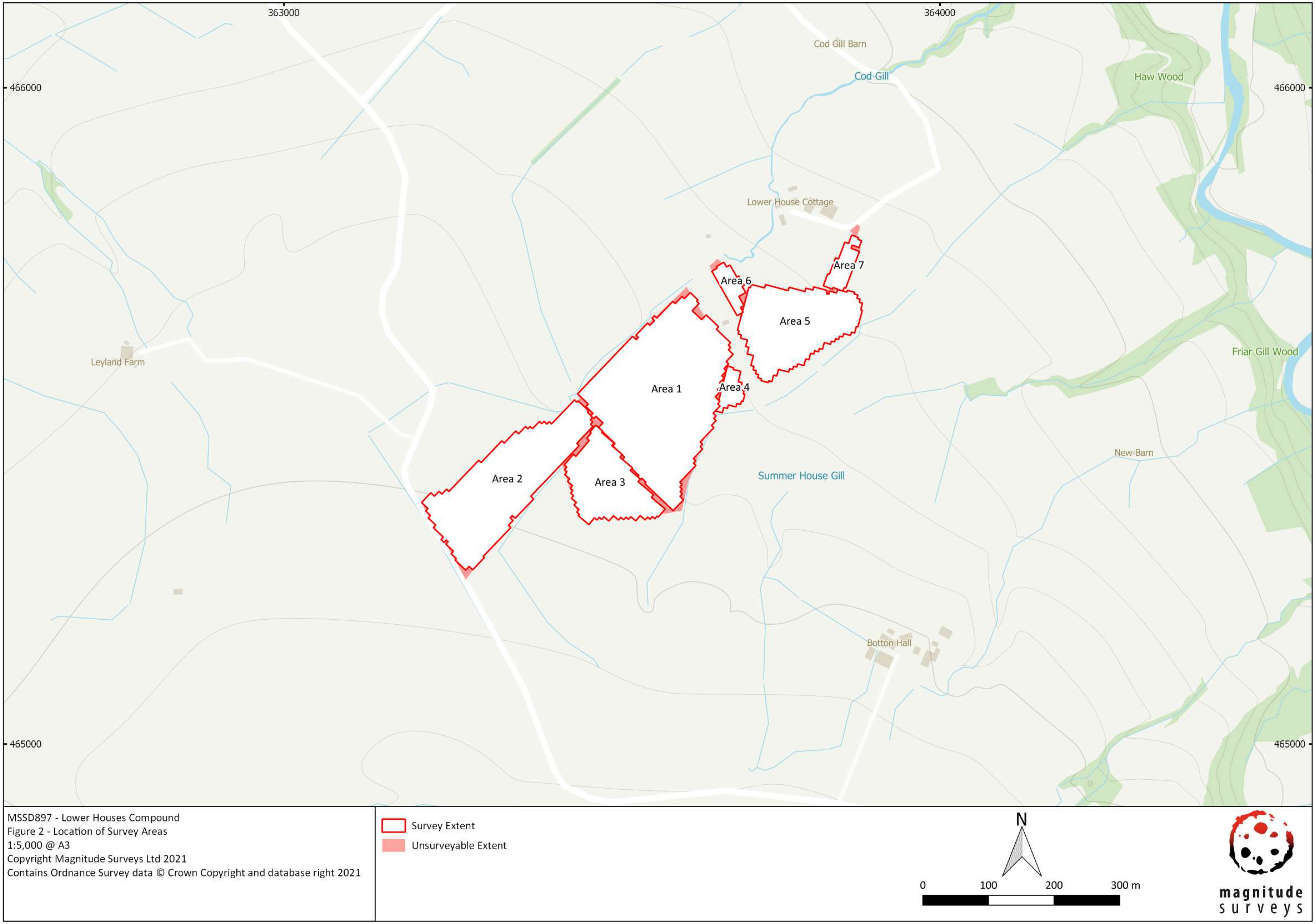
MSSD897 - Lower Houses Compound
Figure 1 - Site Location
1:25,000 @ A4

N

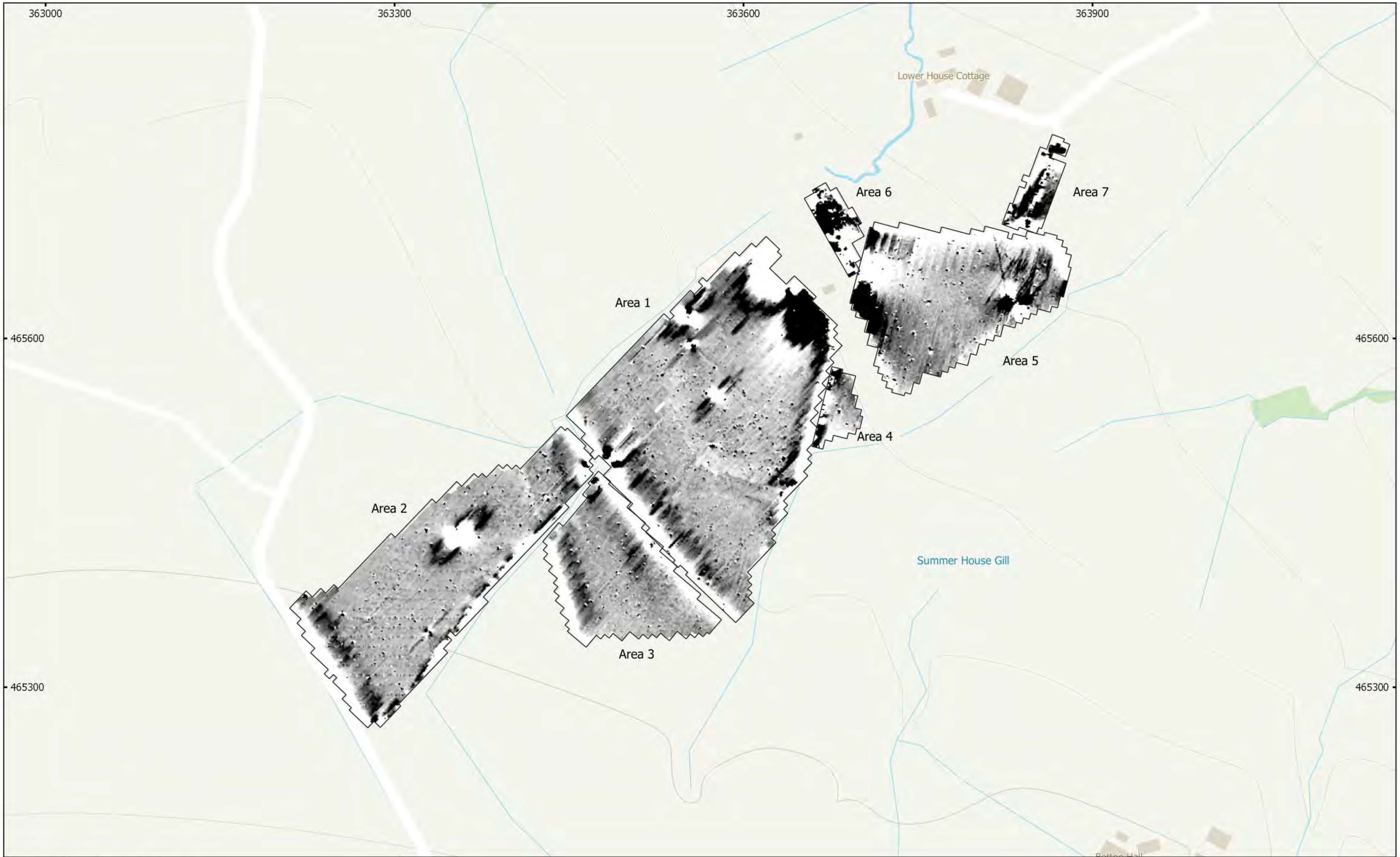
0 0.5 1 km

Site Boundary

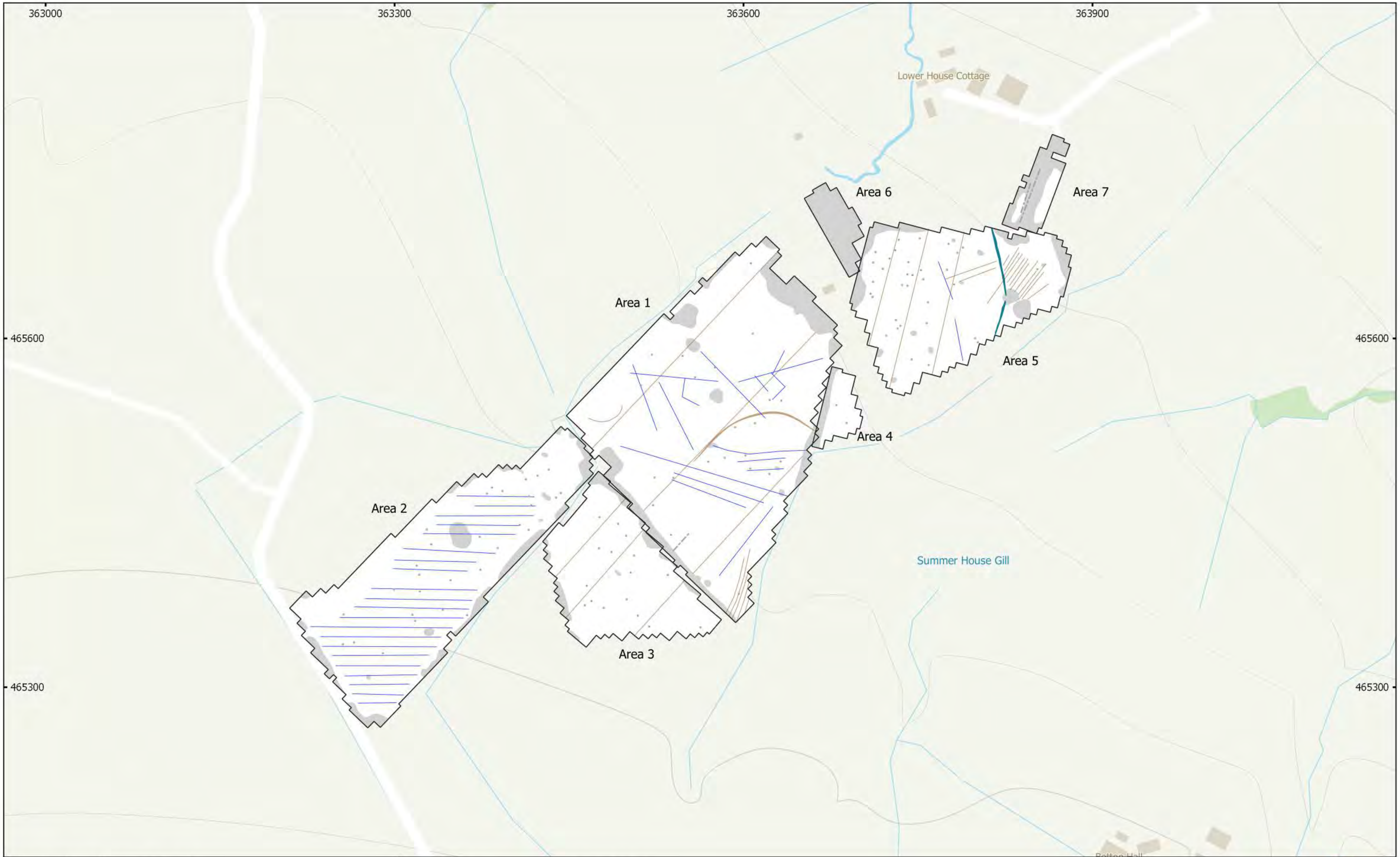
magnitude surveys



MSSD897 - Lower Houses Compound
Figure 2 - Location of Survey Areas
1:5,000 @ A3



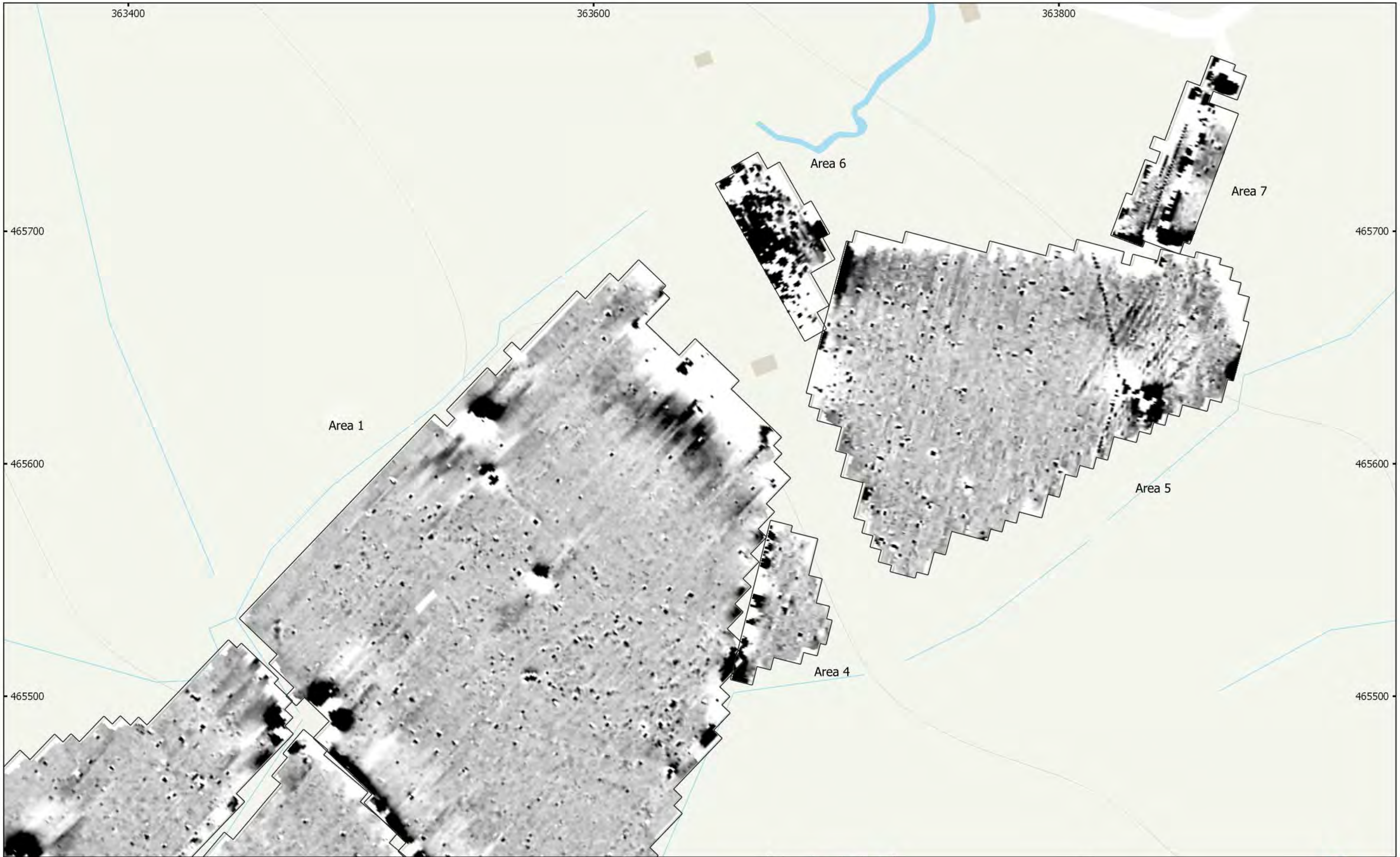
MSSD897 - Lower Houses Compound
Figure 3 - Magnetic Total Field (Lower Sensor)
1:3,000 @ A3



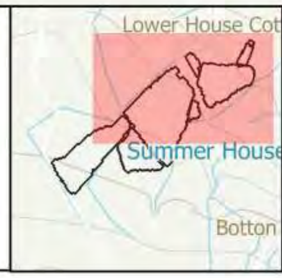
MSSD897 - Lower Houses Compound
Figure 4 - Magnetic Interpretation
1:3,000 @ A3

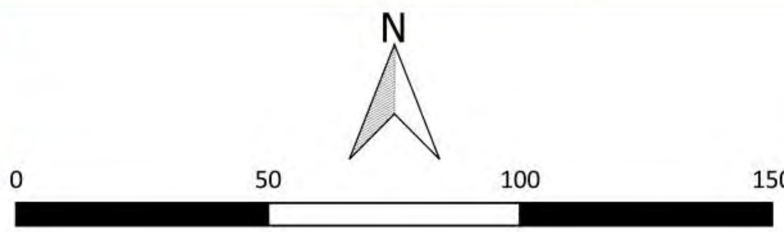
MSSD897 - Lower Houses Compound
Figure 5 - Magnetic Interpretation Over Historical Maps and Satellite Imagery
1:3,000 @ A3

magnitude surveys

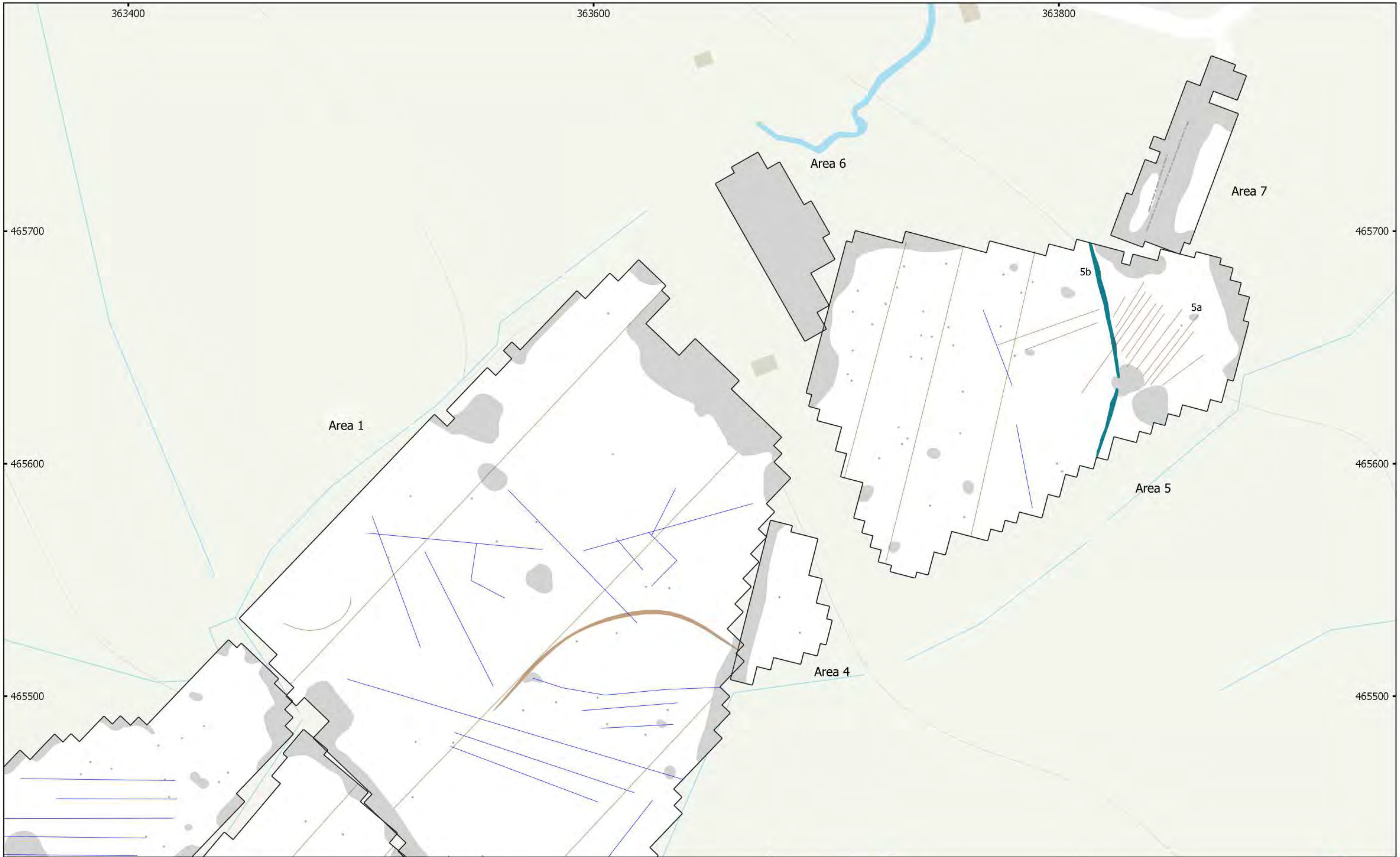


MSSD897 - Lower Houses Compound
Figure 6 - Magnetic Gradient (Northeast)
1:1,500 @ A3





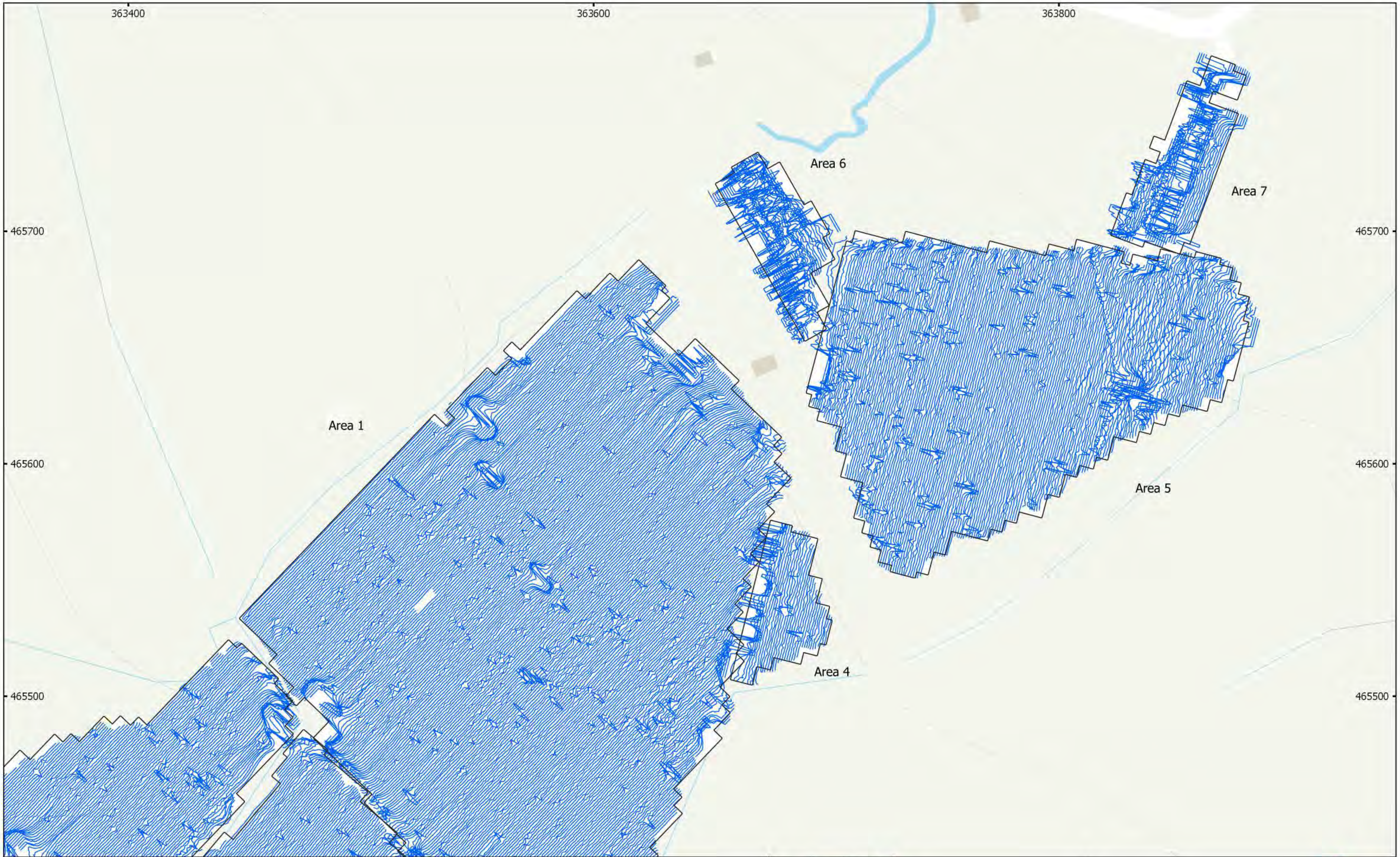
magnitude surveys



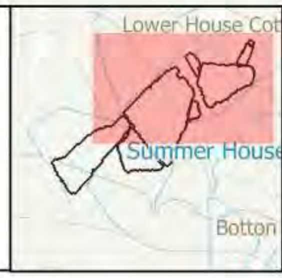
MSSD897 - Lower Houses Compound
Figure 7 - Magnetic Interpretation (Northeast)
1:1,500 @ A3

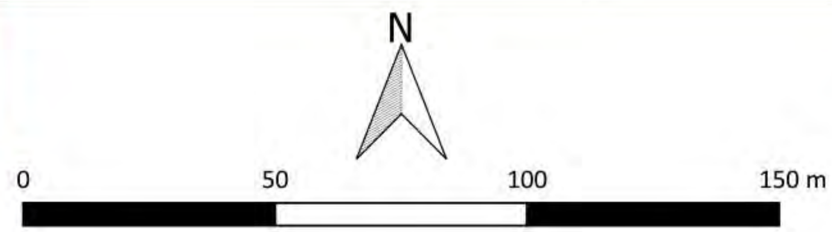
Agricultural (Weak)
Magnetic Disturbance
Undetermined (Strong)
Agricultural (Trend)
Data Artefact
Drainage Feature
Ferrous (Spike)

magnitude surveys

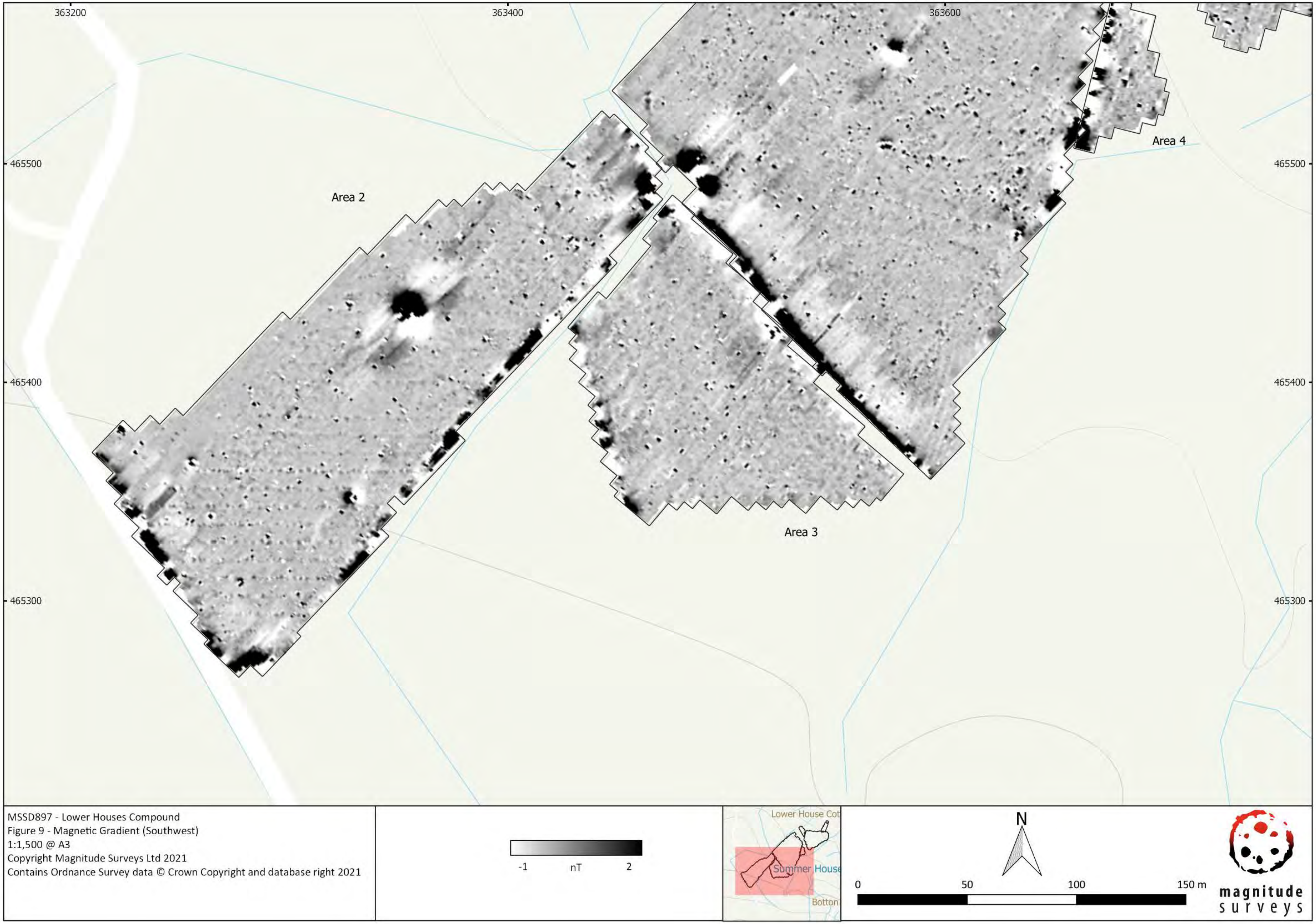


MSSD897 - Lower Houses Compound
Figure 8 - XY Trace Plot (Northeast)
30nT/cm at 1:1,500 @ A3



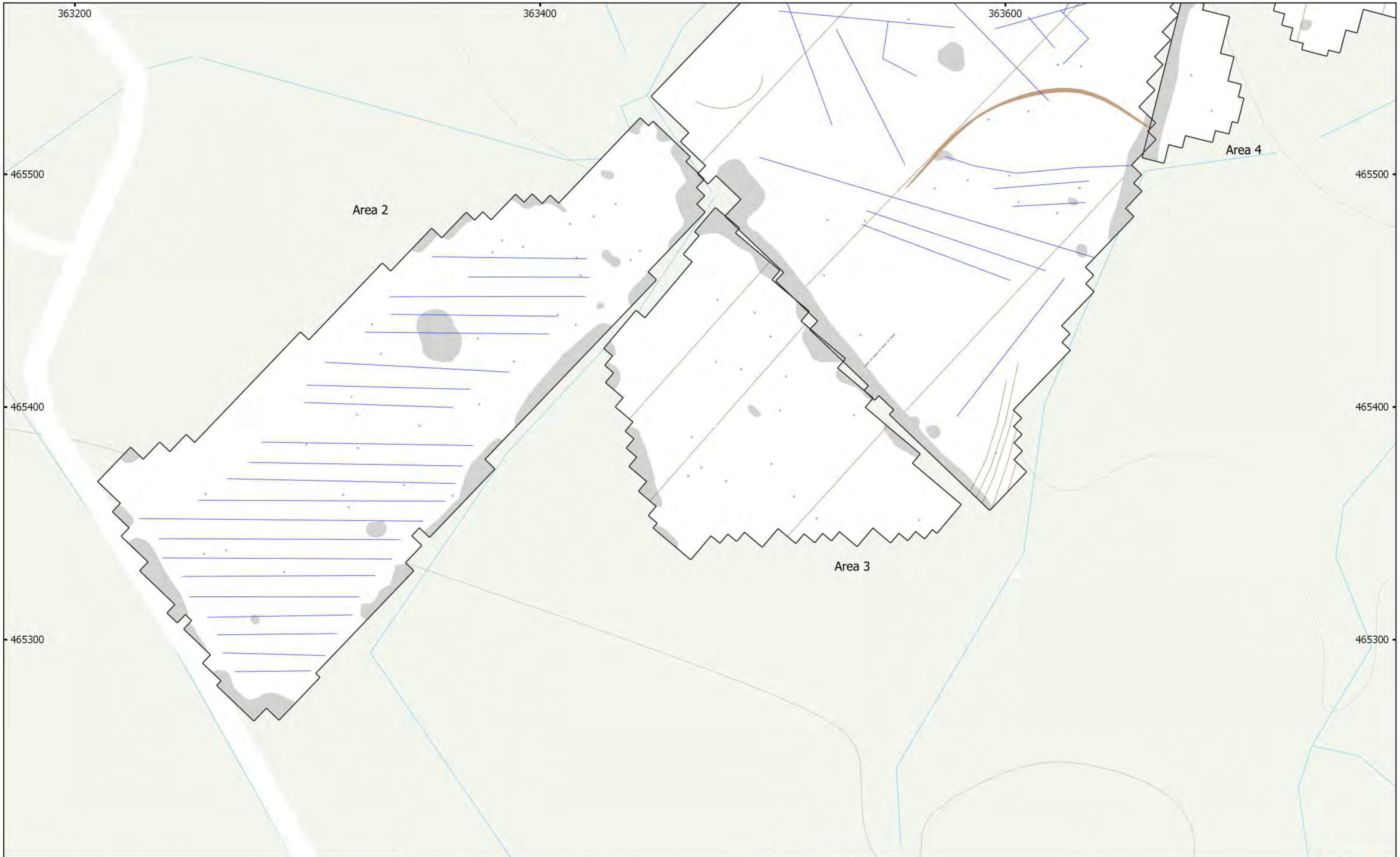


magnitude surveys



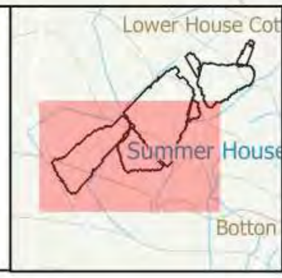
MSSD897 - Lower Houses Compound
Figure 9 - Magnetic Gradient (Southwest)
1:1,500 @ A3

magnitude surveys



MSSD897 - Lower Houses Compound
Figure 10 - Magnetic Interpretation (Southwest)
1:1,500 @ A3

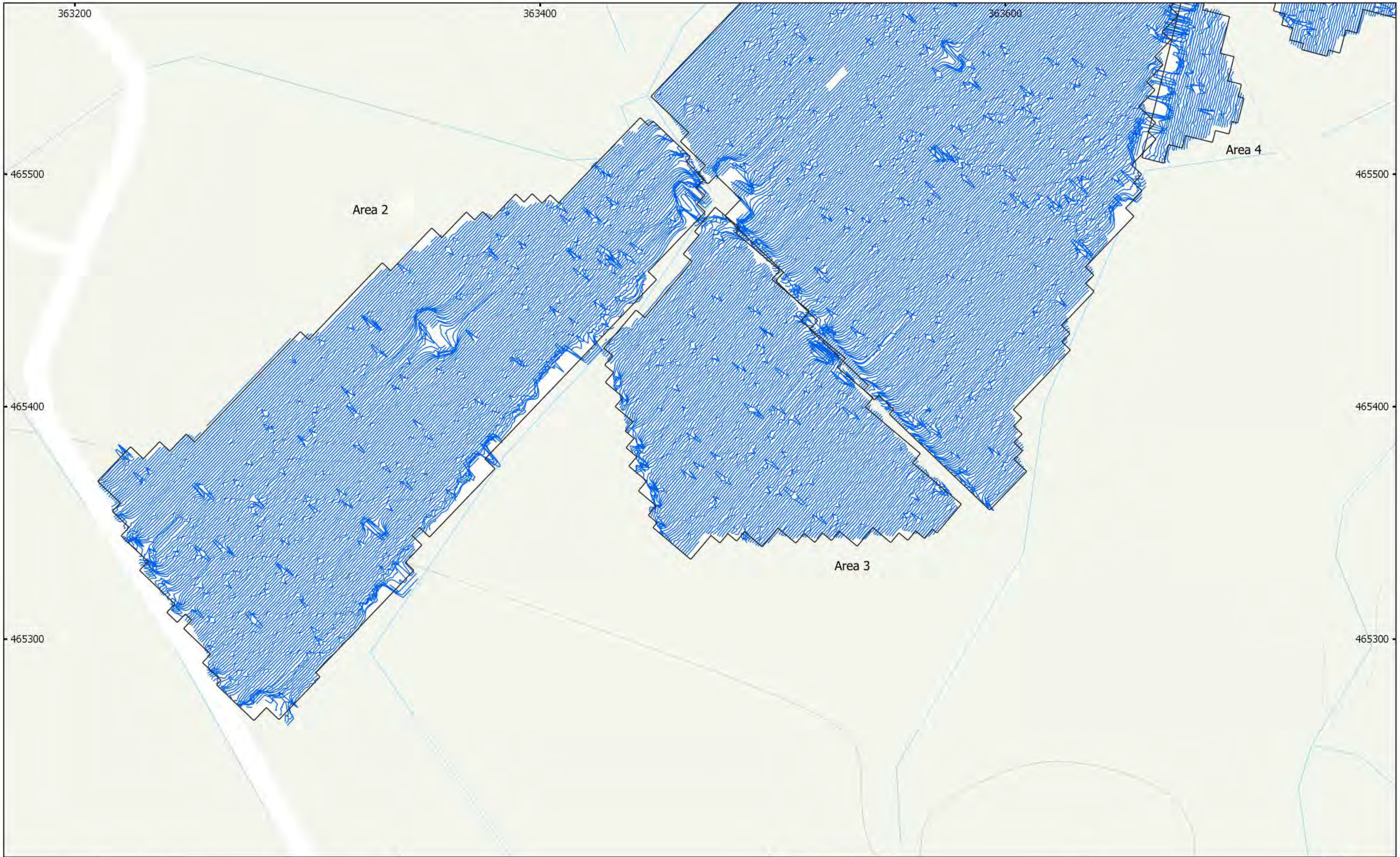
Agricultural (Weak)
Magnetic Disturbance
Agricultural (Trend)
Data Artefact
Drainage Feature
Ferrous (Spike)



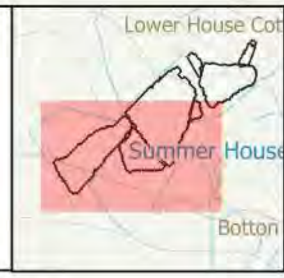
N

0 50 100 150 m

magnitude surveys



MSSD897 - Lower Houses Compound
Figure 11 - XY Trace Plot (Southwest)
30nT/cm at 1:1,500 @ A3



N

0 50 100 150 m

magnitude surveys